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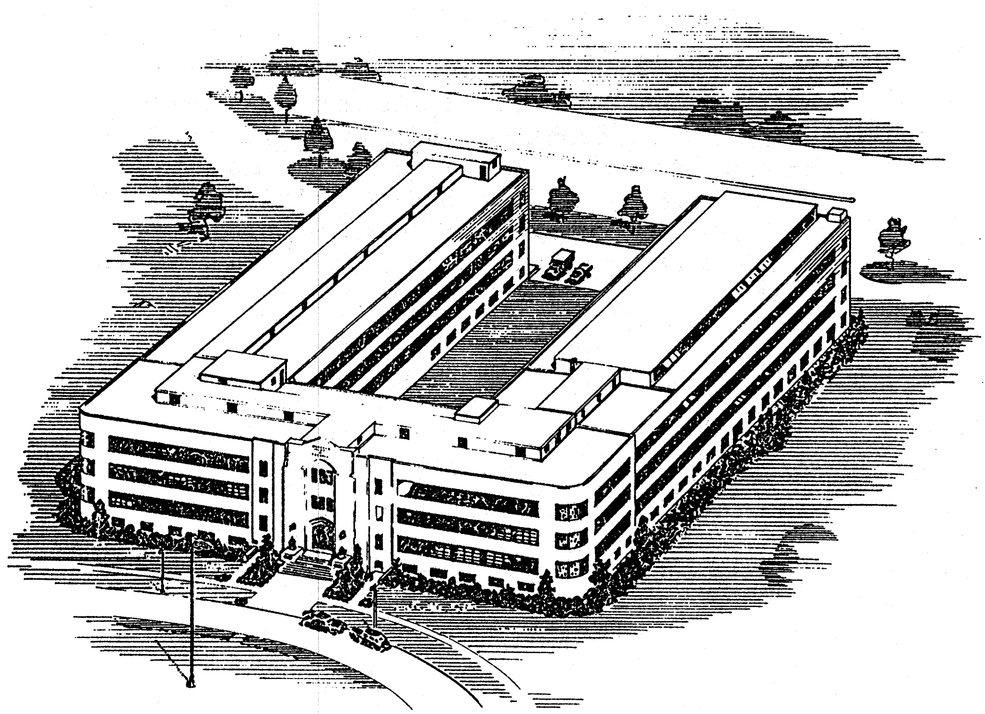
PRODUCTION OF LEAF MEALS FROM VEGETABLE WASTES IN ROTARY ALFALFA DRIERS



ACKNOWLEDGMENT

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PRODUCTION OF LEAF MEALS FROM VEGETABLE WASTES IN ROTARY ALFALFA DRIER

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SUMMARY

A process has been developed whereby leaf meals of good quality can be prepared from vegetable wastes such as pea vines, lima bean vines, broccoli, spinach, and beet tops by fractional drying in high temperature, direct heat rotary driers of the alfalfa type. Since the process proved feasible for wastes of widely different characteristics, presumably wastes other than those tested could be similarly processed to produce good-quality leaf meals.

The total cost of making a ton of leaf meal from pea vines, lima bean vines, broccoli, spinach, and beet tops is estimated to be $51, 45, 108, 68 and 114, respectively, for an individual enterprise. For an operation auxiliary to an existing business, the cost of making a ton of leaf meal from these wastes is estimated to be $43, 38, 90, 58, and 95, respectively. To arrive at the selling price, it is necessary to add only the cost of selling and a margin of profit.

The leaf meals are in most cases richer than alfalfa meal, which is sold on a guaranteed basis of 100,000 I.U. per pound (133 p.p.m.) of carotene and 17 percent protein. With alfalfa meal of this guaranteed composition selling in the Philadelphia market at from $53 to $86 per ton, the production of certain vegetable leaf meals by the methods described herein can be a profitable enterprise in such an area.

PRODUCTION OF LEAF MEALS FROM VEGETABLE WASTES IN ROTARY ALFALFA DRIER

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INTRODUCTION

A process for preparing high-grade vegetable leaf meals from field wastes in moderate-temperature, through-circulation belt driers has been published by the Eastern Regional Research Laboratory[6,7]. This process, which consists in fractional drying at 240° F., did not find wide industrial adoption principally because moderate-temperature belt driers are costly and are less widely used in farm operations than rotary types. Direct-heat, rotary alfalfa-type driers are cheaper per unit of evaporating capacity, are simple to operate, and are widely used for processing farm crops. Therefore the suitability of this type of drier for the preparation of high-carotene, high-protein leaf meals from vegetable wastes has been investigated.

GENERAL DESCRIPTION OF PROCESS

The process (for all wastes) consists essentially of the following steps.

(1) Chop in a rotary forage cutter.

(2) Dry "fractionally," that is, until the leaves become dry and brittle but the stems remain moist and tough.

(3) Detach the dry leaves from the moist stems. This is done by the fans through which the material passes.

(4) Separate the leaf fraction from the stem fraction by means of a vibrating screen equipped with suitable sieves.

(5) Collect partially dried stems for further drying or disposal, depending on their value.

A few minor adjustments have to be made, depending on the waste to be dried. These adjustments, which involve size of cut in rotary forage cutter and number and mesh of sieves for the vibrating screen, are discussed under **DETAILS OF THE PROCESS.**

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[6] PROCESSING VEGETABLE WASTES FOR HIGH-PROTEIN, HIGH-VITAMIN LEAF MEALS, BY DAVID A. COLKER AND RODERICK K. ESKEW. U. S. DEPT. AGR., BUR. AGR. AND INDUS. CHEM. AIC-76 (EASTERN REGIONAL RESEARCH LABORATORY). MARCH 1945. (PROCESSED.)

[7] PREPARATION AND USE OF LEAF MEALS FROM VEGETABLE WASTES, BY J. J. WILLAMAN AND RODERICK K. ESKEW. U. S. DEPT. AGR. TECH. BULL. 958. OCTOBER 1948.

Figure 1 is a schematic representation of a commercial installation for the foregoing steps.

DETAILS OF THE PROCESS

Chopping

In order that the wastes may be easily conveyed and properly dried, they should be chopped into small pieces. The chopping should be done with a minimum of bruising because bruised leaves tend to lose carotene on standing and during drying; for this reason cutter knives should be kept sharp. To minimize bruising, the fan is removed from the forage cutter, and the chopped waste is delivered directly from the knives to the conveyor of the drier. No screen is used beneath the knives. The chopped plant should be fed directly to the drier to keep loss of carotene at a minimum.

Suitable chopping can be done with a forage cutter having "lawn mower" type knives. For pea and lima bean vines, the knives should be set for a cut of one-fourth inch. For broccoli, spinach, and beet tops, they should be set for a cut of 1 inch. The actual average size of the cut waste, however, is somewhat larger than the setting on the cutter.

Drying

EQUIPMENT

The drier used in our investigations (Fig. 2) was a small, commercial-size, multiple-pass, oil-fired rotary drier. The rotating body, which is 16 feet long, is made up of three concentric cylinders, 2-1/2, 5, and 7 feet in diameter, respectively. The inner cylinder is the combustion chamber. The oil burner is mounted at one end of this cylinder, and protrudes from the main body, as shown at the right side of Figure 2. The drying air, drawn in by an exhaust fan through openings adjacent to the burner, is heated by mixing with the products of combustion.

The material to be dried falls from the chopper on the elevator, from which a screw feeder forces it into the left end of the drier. Here it meets the heated air and products of combustion and is carried by them, in the annular space between the inner cylinder and the 5-foot cylinder, to the right end of the body, then back between the 5-foot cylinder and the outer one to the left end. Here the gases and the dried material enter the exhaust fan, which delivers them to the cyclone separator adjacent to the drier. The hot gases escape through the top of the separator, and the dried material falls through the bottom. Here a stream of cold air from another fan picks up the dried material and sends it to a cooling cyclone separator. The velocity of this air is insufficient to pick up stones or gravel; any such material that has entered the drier falls out through a tee in the duct at this point. From the bottom of the second cyclone, the dried material falls to the screen.

Presumably other properly designed driers of the rotary type, single or multiple-pass, could be employed.

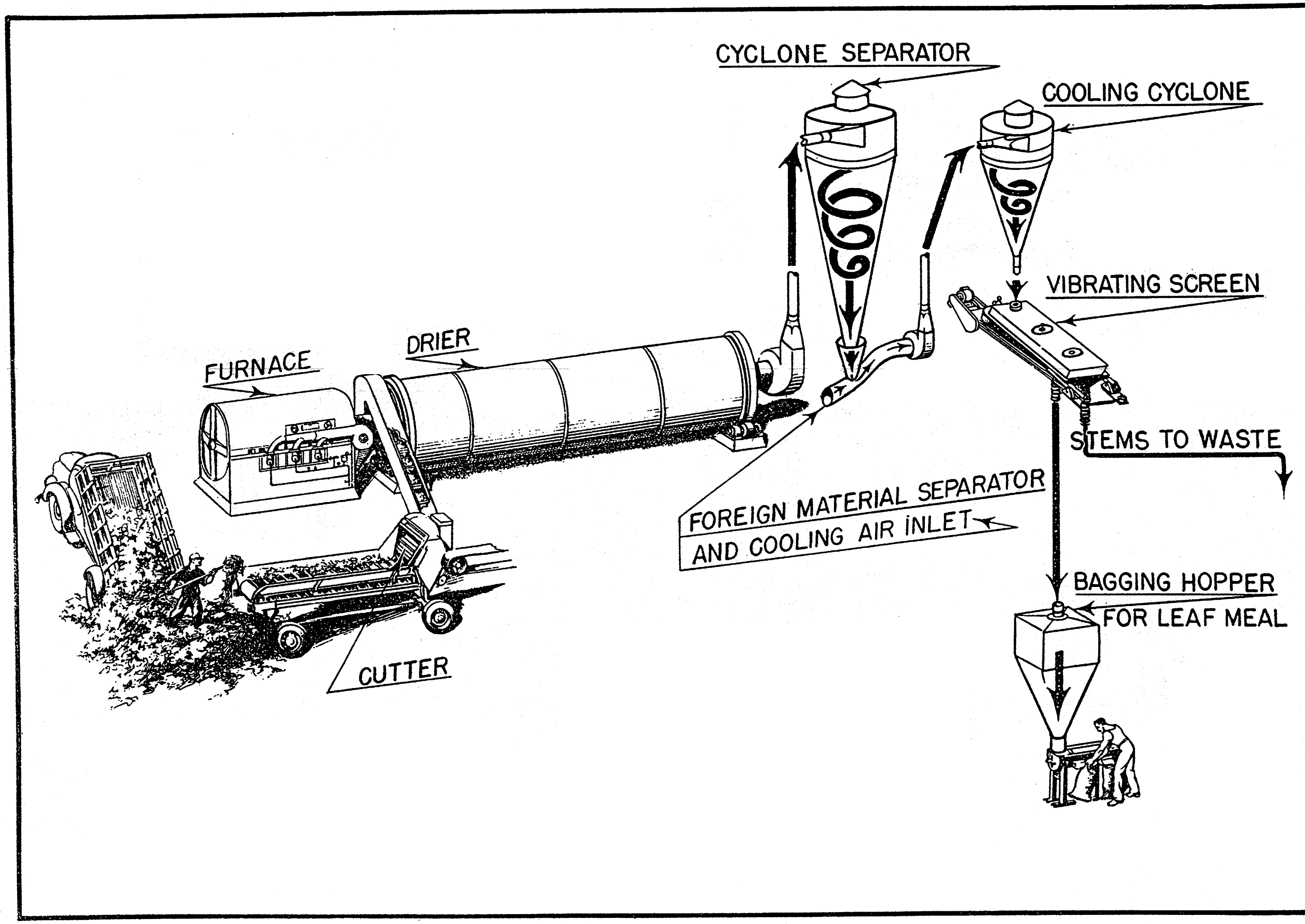

FIGURE I. PRODUCTION OF LEAF MEALS FROM VEGETABLE WASTES IN A ROTARY ALFALFA DRIER.

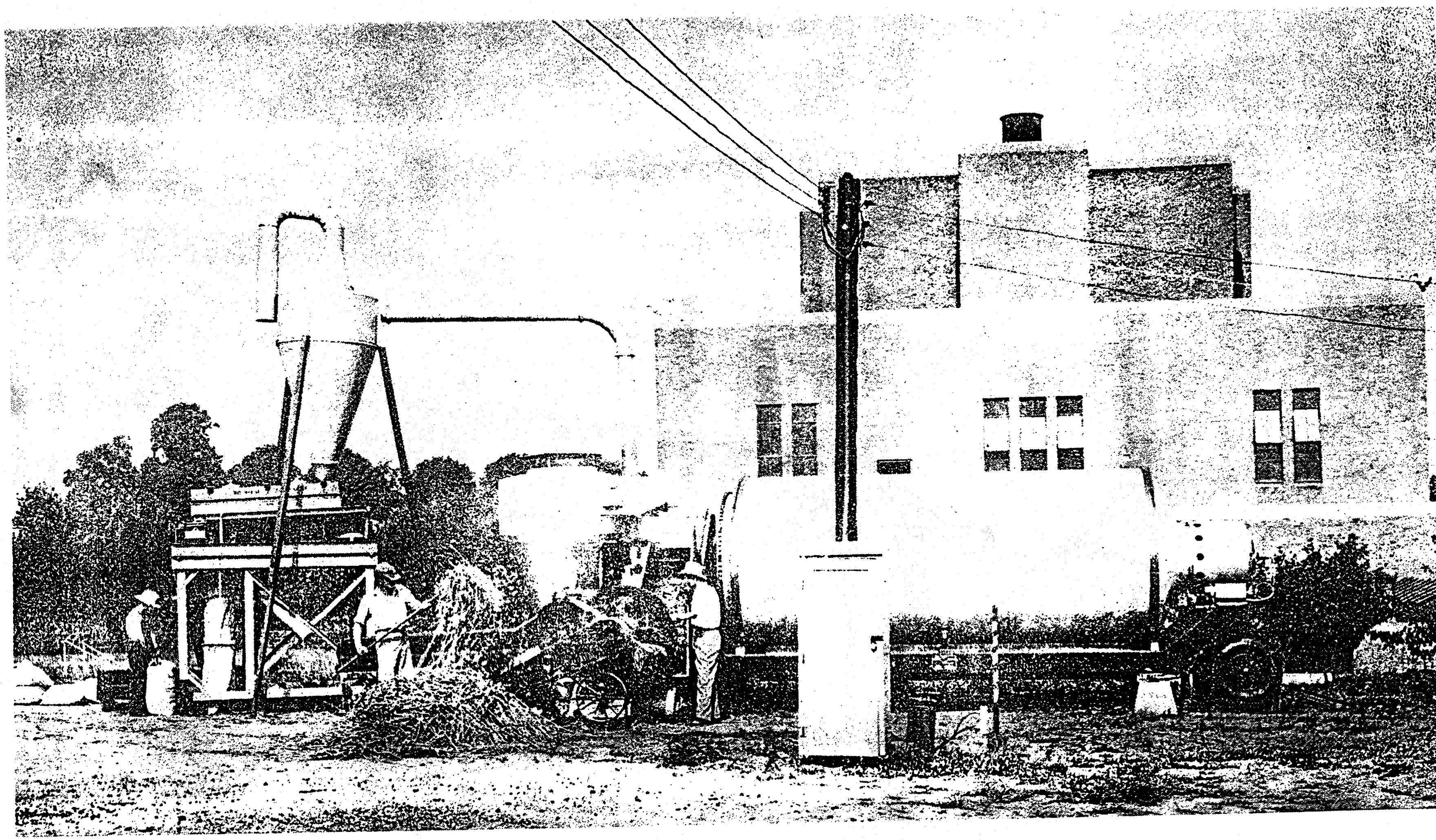

FIGURE 2. INSTALLATION USED IN THE DRYING EXPERIMENTS.

TECHNIQUE

The method of fractional drying, which consists of drying until the leaves are just dried, but the stems remain moist and tough, was developed first with a belt drier[6,7]. It has been found in this work to be applicable also to direct-heat rotary driers for four of the five wastes used. This system of drying has advantages over total drying, that is, drying the stems as well as the leaves, both from the point of view of economy and quality of the product. Although the stem portion contains some of the valuable constituents, the leaves contain by far the bulk of the carotene and protein. Also, the stem portion dries much more slowly than the leaf portion. Therefore, if the stems were dried completely, the more valuable leaves would be subject to over-drying. Crushing or splitting the stems to increase their drying rate would injure the leaves and would also result in an inferior product. From an economic point of view, fractional drying increases the hourly leaf meal output of the drier and decreases the fuel consumed per ton of meal produced. It minimizes unnecessary evaporation of water from the stems, which are screened out in preparing leaf meal. Even though the stems are to be used, it is preferable to dry them after separation from the leaves.

EFFECT OF TEMPERATURE

When availability of the waste permitted, high temperature studies were made in the rotary drier at inlet temperatures of about 850° , 1000° , and 1200° F. The exhaust temperature was automatically set by adjusting the feed rate so that the leaf portion of the fractionally dried product had the desired moisture content, for example, 10 percent. The maximum inlet temperature studied was determined by the maximum temperature possible in the drier, that is, 1250° F.

To evaluate the effect of high temperature drying on the valuable constituents of the vegetable wastes studied, simultaneous tests were made in the through-circulation belt drier at 240° F. Because of the difficulty of obtaining representative samples of the fresh waste, an absolute evaluation based on the fresh waste could not be obtained. For this reason, the belt-drier process was used as the standard by which the rotary drier was appraised.

Table I shows a comparison of the results with the high-temperature and the moderate-temperature driers on the basis of over-all carotene retention and carotene content in the leaf meal per ton of fresh waste. The carotene values rather than the protein values (N x 6.25) were used as a basis of evaluation, because protein is not affected by drying temperatures in the range studied.

EFFECTS OF DRYING CONDITIONS[1] ON RETENTION OF CAROTENE AND PROTEIN IN PROCESSING VEGETABLE WASTES

EGETABLE WASTE	ROTARY DRIER AIR TEMPERATURE INLET	ROTARY DRIER AIR TEMPERATURE EXIT	CAROTENE IN LEAF MEAL PER TON OF FRESH WASTE ROTARY DRIER	CAROTENE IN LEAF MEAL PER TON OF FRESH WASTE BELT DRIER[1]	RETENTION OF CAROTENE IN WHOLE PRODUCT ROTARY DRIER	RETENTION OF CAROTENE IN WHOLE PRODUCT BELT DRIER[1]	RETENTION OF CAROTENE IN ROTARY DRIER COMPARED WITH THAT IN BELT DRIER[1]	PROTEIN IN WHOLE PRODUCT ROTARY DRIER	PROTEIN IN WHOLE PRODUCT BELT DRIER[1]	RETENTION OF PROTEIN IN ROTARY DRIER COMPARED WITH THAT IN BELT DRIER[1]
	°F.	°F.	Lbs.	Lbs.	p.p.m.	p.p.m.	%	%	%	%
Pea vines	837	281	0.022	0.015	60.7	58.7	3.4	13.2	12.2	8.2
	1032	293	.026	.014	77.0	80.9	-4.8	14.4	14.4	.0
Broccoli	915	322	.080	.083	442.0	451.0	-2.0	33.2	34.0	-2.4
	1090	336	.070	.075	370.0	408.0	-9.3	34.1	33.6	1.5
	1220	334	.063	.084	348.0	448.0	-22.3	34.6	34.4	.6
Lima bean vines	863	280	.040	.036	97.7	95.8	2.0	9.7	9.4	3.2
	1040	290	.044	.043	119.7	132.1	-9.4	13.6	12.1	12.4
	1245	294	.027	.041	72.0	113.2	-36.4	10.2	9.6	6.3
Spinach	896	324	.058	.068	264.0	311.0	-15.1	28.0	27.6	1.5
	1035	340	.078	.092	401.0	474.0	-15.4	36.0	35.1	2.4
	1223	331	.067	.079	361.0	427.0	15.4	31.9	33.9	-5.9
Beet tops	863	322	.035	.049	183.0	253.0	-27.6	20.7	23.0	-10.0
	1035	330	.039	.048	214.0	255.0	-16.1	19.8	20.7	-4.4

1 *In the belt drier, the inlet air temperature was 240° F.*

Table II gives the composition of the leaf meal and the stem fraction, moisture contents, and yields at drying conditions considered optimum on the basis of drier capacity and retention of the valuable constituents. The carotene values are probably conservative, since an unavoidable delay of 5 to 6 hours occurred from the time of harvesting until the wastes were processed. Delay results in a loss in carotene, especially in pea vines and lima bean vines, which are bruised in the vining operations.

Pea Vines: Drying of pea vines was studied at two inlet temperatures, namely, 840° and 1030° F. The average exhaust temperatures which gave a fractionally dried product were 281° and 293° F., respectively. As shown in Table I, retention of carotene in the rotary drier at both drying temperatures was about equal to that in the belt drier. However, on the basis of pounds of carotene in leaf meal per ton of fresh waste, the rotary drier method was superior. This was true because it was possible to dry fractionally in the rotary drier, but not in the belt drier, thus permitting better separation in the former. Therefore, pea vines can be dried satisfactorily at about 1050° F. inlet temperature or perhaps at somewhat higher temperatures. Sufficient material was not available to make drying tests at 1200° F.

Broccoli: Three drying conditions for broccoli were studied--inlet temperatures of 915°, 1090° and 1220° F., and exit temperatures of 322°, 336° and 334° F., respectively. As compared with that in the belt drier process, retention of carotene in the rotary drier decreased as the inlet temperature increased (Table I). Loss of carotene at inlet temperatures of 915°, 1090° and 1220° F. was 2.0, 9.3, and 22.3 percent, respectively. Since loss at the highest temperature was excessive, such an inlet temperature is not recommended. Despite the slightly greater destruction of carotene at the intermediate temperature, this temperature is preferable to the low temperature because it increases drier capacity 30 percent. Although the exhaust temperatures at the intermediate and high inlet temperatures were about the same, loss of carotene was much greater at the high temperature--22.3 and 9.3 percent, respectively. Yields of carotene per ton of fresh waste at the intermediate and low temperatures were about the same as those obtained with the belt drier.

Lima Bean Vines: The whole viner waste was used in making these tests, instead of the "apron" fraction as described in AIC-76[6] and Technical Bulletin 958[7]. The "apron" fraction from the viners consists mainly of leaves and a small amount of stems. This fraction, however, was not available in the large quantities necessary for our studies, and it may not be available for large-scale production.

The inlet and outlet temperatures at which the vines were dried were 863° and 280°, 1040° and 290°, 1245° and 294° F., respectively. Again the retention of carotene decreased with increase of inlet temperature, despite the fact that the outlet temperatures at the intermediate and high inlet temperatures were practically the same. On the basis of carotene retention

TABLE II

YIELDS AND ANALYSES OF VEGETABLE LEAF MEALS MADE IN THE ROTARY DRIER AT RECOMMENDED TEMPERATURES

				LEAF MEAL							STEMS						
							ANALYSES[2]							ANALYSES[2]			
ETABLE ASTE	TEMPERATURE OF AIR INLET °F.	TEMPERATURE OF AIR EXIT °F.	MOIS-TURE IN PLANT %	YIELD[1] %	MOIS-TURE %	YIELD[2] %	CARO-TENE[3] p.p.m.	PROTEIN %	FIBER %	TOTAL ASH %	YIELD[1] %	MOIS-TURE %	YIELD[2] %	CARO-TENE[3] p.p.m.	PROTEIN %	FIBER %	TOTAL ASH %
occoli	1090	335	90.0	7.1	5.75	67.1	518	39.5	8.5	---	7.1	52.9	32.9	69	23.2	16.7	---
inach ield waste	1225	330	90.7	9.7	4.23	100.0	361	31.9	9.15	31.1	---	---	---	---	---	---	---
et tops	1050	330	90.4	7.7	3.21	77.6	264	20.8	7.55	32.8	3.4	37.5	22.4	41	16.3	12.9	23.4
ma bean vines[4]	1050	290	76.0	11.7	6.05	45.6	203	15.2	20.5	20.8	16.9	34.4	46.3	31	12.0	51.8	---
ea vines	1050	290	78.8	12.4	9.00	53.0	115	16.9	22.5	---	16.1	38.2	47.0	34	11.6	25.3	-

Fresh basis.

Moisture-free basis.

P.p.m. carotene x 754 = international units per pound.

Soil screened from the dried leaf fraction amounted to 2 percent on the fresh basis and 8 percent on the moisture-free basis. It contained 4 percent moisture and had the following analyses: Carotene, 131 p.p.m.; protein, 13 percent; fiber, 9 percent; and total ash, 45 percent.

per se, the lowest temperature investigated was the best. The loss at the intermediate temperature was only slightly greater (9.4 percent), however, and this temperature is recommended, since it increased the drier capacity by about one-third. The highest inlet temperature is not recommended because of the excessive loss of carotene (36 percent). Again, as in drying broccoli, at the low and intermediate inlet temperatures yields of carotene per ton of waste were as good as those obtained with the belt drier.

Spinach Waste: The spinach waste studied consisted mainly of leaf, with little stem material. Since the small amount of stem material dried to about the same extent as the leaf, a whole meal was prepared. Three inlet temperatures were investigated, namely, 900°, 1035° and 1225° F. The outlet temperatures were 324°, 340° and 331° F., respectively. Loss of carotene was the same at all three temperatures--about 15 percent (Table I). In all cases, the yields of carotene per ton of waste were lower than in the belt drier. The highest inlet temperature is recommended, since it increased production of meal almost 80 percent over that at the low temperature and about 45 percent over that at the intermediate temperature.

Beet Tops: The optimum temperature for drying beet tops was not determined, because enough waste to complete the studies was not available. Only one inlet temperature--1035° F.--was tested with reasonably fresh material. Table I shows that loss of carotene at this temperature was about 16 percent. Although this loss was moderately high, a good quality leaf meal was produced. Therefore, drying beet tops in a rotary drier may be considered feasible, at least as far as quality of product is concerned.

A test was made at 860° F. with beet tops stored overnight. Although the waste showed no deterioration, as determined by the belt-drier test, the results were contrary to those obtained with all other wastes studied, in that the apparent loss of carotene was greater at the lower inlet temperature--approximately 28 percent. Under these circumstances, no definite conclusion can be drawn.

SEPARATION

When the fractionally dried material passes through the drier and the fans, the fan blades detach the friable leaves from the moist tough stems. The mixture is passed over a vibrating screen equipped with sieves having openings that allow the fragmented leaf to pass through, thereby separating it from the stems. For lima bean and pea vines, a 5-mesh sieve having 0.16-inch square openings is suitable; an 8-mesh sieve having 0.097-inch square openings is suitable for broccoli, beet tops, and spinach. It was found that the screened spinach stems, which represented 7 percent of the total, could be added to the leaf meal, since they were dry and were high in protein and carotene. No screening is necessary for spinach waste.

In drying lima bean vines, a 60-mesh sieve should also be provided for removal of the soil. This procedure is not altogether effective, as indicated by the ash content of the leaf meal retained on a 60-mesh screen (Table II). Removal of soil is complicated by the fact that the leaf fines pass through with the soil and hence are lost. Therefore, 60-mesh is recommended as a compromise between complete soil removal and retention of leaf constituents.

A method of harvesting lima bean vines in which the plant is cut above ground instead of being pulled up with the root attached is under investigation at certain farms. If the cutting method can be used successfully, the soil problem will be minimized.

For spinach and beet tops, however, removal of soil with a 60-mesh sieve was found inadvisable because so much leaf meal was removed with the soil.

STEM DRYING

A question is posed as to the utilization, if any, of the partly dried stems obtained in the separation step. Their value as a source of carotene is practically negligible. Stems from some of the wastes, however, are rich in protein (Table III). Therefore, when justified by their protein content, the stems should be accumulated and dried at the end of the operating day. To expose more surface and thereby increase their drying rate, they should be split or crushed before drying. Since preservation of carotene is not a factor, inlet temperatures as high as 1250° F. or higher can probably be used. Screened broccoli stems, for example, represent about 33 percent of the total solids in the waste. Since the drier has an average evaporating capacity of 2350 pounds of water per hour at an inlet air temperature of 1250° F., it should be capable of drying the crushed, partly dried stems accumulated in 23 hours' operation in less than 1 hour. This would produce 1550 pounds of stem meal in a portable drier of the type used in our work.

As shown in Table II, broccoli leaf meal should contain about 518 p.p.m. of carotene and 39.5 percent protein. The dried stems (assuming all the carotene were lost at the high temperature employed in drying them) would contain no carotene but about 23 percent protein. A whole broccoli meal consisting of two-thirds leaf meal and one-third separately dried stems would have approximately the following analysis: carotene, 346 p.p.m.; protein, 34 percent; fiber, 11.3 percent. Guaranteed alfalfa meal is largely sold on the basis of 133 p.p.m. of carotene, 17 percent protein and about 27 percent fiber.

STORAGE

No work was done on the storage of leaf meals produced in the rotary direct-fired drier. It is expected, however, that storage conditions that have been found suitable for alfalfa meals will also be suitable for vegetable leaf meals.

COST ESTIMATES

Fixed Unit

Estimates of the cost of making vegetable leaf meals, by the process recommended here have been made on two bases--(a) as an individual business enterprise and (b) as an operation auxiliary to an existing business, for example, vegetable processing. The cost for Case (b) is less because certain expenses are shared with the existing business. For example, items such as

TABLE III

YIELDS AND ANALYSES OF PARTIALLY DRIED STEMS FROM VEGETABLE WASTES

Stems	Yield[1] of original waste %	Moisture %	Protein[1] %	Crude Fiber[1] %
Spinach	7	10	27.6	15.3
Broccoli	33	53	24.0	16.7
Beet tops	22	38	16.2	12.9
Kale	43	62	16.1	9.9
Pea vines	47	38	10.6	25.3
Carrot tops	42	46	10.0	18.0
Lima bean vines	46	34	7.7	51.8

[1] *Moisture-free basis.*

land and site preparation, roads and parking areas, erection of manufacturing equipment, power, engineering fees, indirect labor, and indirect expenses, would be lower than for Case (a). The costs given are for a plant located in the Middle Atlantic States. These estimates assume an installation of two rotary alfalfa-type driers, each having a rated evaporative capacity of 6000 pounds of water per hour for the drying of alfalfa. They include the costs of all the auxiliary equipment, a building for housing the screening and bagging facilities, and warehouse space for one week's production. The driers are not housed. Table IV shows capital costs.

The costs assume that the plant will operate 24 hours a day for at least 150 working days per year. A period significantly less than this might well result in an unprofitable enterprise.

The figures for "Costs to Make" given in Table V for Case (a) and in Table VI for Case (b), include not only the actual production costs but all other items, such as administration, general expenses, research, interest on investment, and working capital. Thus, to arrive at a selling price it is necessary to add only the cost of selling and a margin of profit.

Table VII gives the engineering data on which the cost estimates are based.

Portable Unit

Consideration was given to the feasibility of operating an itinerant portable unit employing a drier of the type used in our work. It was found that under such conditions the cost to make leaf meal would be from 30 to 45 percent higher than the figures shown for Case (a).

COMMERCIAL USES

Although no feeding tests have been made on vegetable leaf meals prepared in a direct-heat drier, there is no reason to expect that they will be different from leaf meals of comparable composition prepared in a belt drier. Data have been published on feeding tests with leaf meals prepared at the Eastern Regional Research Laboratory in a low-temperature belt drier.[7,8,9,10,11,12,13]

8 A Preliminary Investigation on the Use of Certain Dried Vegetable Wastes as Poultry Feeds, by A. E. Tomhave, Edmund Hoffmann, E. G. Kelley, M. E. Wall and D. A. Colker. Delaware Agr. Expt. St. Bull. 247. April 1944.

9 Broccoli Leaf Meal for Alfalfa Meal in Broiler Rations, by Edmund Hoffmann, A. E. Tomhave, Edward G. Kelley and Monroe E. Wall. Feedstuffs 17 (8): 25-27. 1945.

10 Carotene from Vegetable Leaf Wastes Compared with Vitamin A in Chick Rations, by W. C. Skoglund, A. E. Tomhave, and A. F. Kish. Delaware Agr. Expt. Sta. Bull. 268, July 1947.

11 Carotene from Vegetable Leaf Wastes Compared with Vitamin A in Laying Rations, by W. C. Skoglund, A. E. Tomhave, and C. W. Mumford. Poultry Sci. vol. XXVIII, no. 2, p. 298-300, March 1949.

12 Composition and Apparent Digestibility of the Carbohydrate and Other Constituents of Pea and Lima Bean Vines When Fed to Sheep, by Max Phillips, C. O. Miller, and R. E. Davis. J. Agr. Research vol. 73, p. 177-187. 1946.

13 Apparent Digestibility by Sheep of Lignin in Pea and Lima Bean Vines, by R. E. Davis, C. O. Miller and I. L. Lindahl. J. Agr. Research vol. 74, p. 285-288. 1947.

TABLE IV

CAPITAL COSTS OF PROCESSING VEGETABLE WASTES IN ROTARY DRIER

Item	Case a		Case b	
Land and site preparation	$ 850		$ 610	
Roads and parking areas	3,500		300	
Buildings	7,175		7,175	
Equipment, manufacturing				
Cutters	2,340		2,340	
Driers	38,515		38,515	
Vibrating screen	3,430		3,430	
Blower	370		370	
Conveyor, screw	745		745	
Conveyor, belt	1,550		1,550	
Bagging heads	30		30	
Piping, cyclones	170		170	
Scales, hand tools, and small tools	125		125	
Stacker	580		580	
Erection of equipment, manufacturing	11,965		9,570	
Piping and ductwork	240		240	
Lighting, installed	1,215		1,075	
Power, installed	5,000		4,225	
Transportation facilities	2,600		2,600	
Freight on equipment	960		960	
Office furniture and fixtures	740		215	
Contingencies	8,530		7,480	
Engineering fees	15,990		11,225	
Total fixed capital		106,620		93,530
Working capital	15,000	15,000	12,000	12,000
Total capital		121,620		105,530

TABLE V

DAILY COSTS TO MAKE LEAF MEAL FROM VEGETABLE WASTES IN ROTARY DRIER - Case a (Individual Enterprise)

Item	Pea vines		Broccoli		Lima bean vines		Spinach		Beet tops		Broccoli stems	
Prime cost												
Raw materials	Nil		Nil		Nil		Nil		Nil		Nil	
Labor	$96.00		$72.00		$96.00		$72.00		$72.00		$120.00	
Total		96.00		72.00		96.00		72.00		72.00		120.00
Indirect materials												
Bags	49.20	49.20	21.20	21.20	56.40	56.40	36.00	36.00	20.00	20.00	402.00	402.00
Factory overhead												
Indirect Labor												
Supervision	28.00		28.00		28.00		28.00		28.00		28.00	
Watchmen and yardmen	18.88		18.88		18.88		18.88		18.88		18.88	
Mechanics, etc.	16.00		16.00		16.00		16.00		16.00		16.00	
Office help	9.33		9.33		9.33		9.33		9.33		9.33	
Indirect expense												
Insurance	3.55		3.55		3.55		3.55		3.55		3.55	
Taxes	14.22		14.22		14.22		14.22		14.22		14.22	
Interest and fixed capital	35.54		35.54		35.54		35.54		35.54		35.54	
Workmen's compensation	1.83		1.53		1.83		1.53		1.53		2.13	
Depreciation	98.16		98.16		98.16		98.16		98.16		98.16	
Maintenance, repairs and renewals	106.24		106.24		106.24		106.24		106.24		106.24	
Power	14.55		14.55		14.55		14.55		14.55		14.55	
Oil, fuel	89.30		89.34		89.26		115.02		88.80		115.20	
Gasoline	2.20		2.20		2.20		2.20		2.20		2.20	
Factory supplies	3.19		3.19		3.19		3.19		3.19		3.19	
Miscellaneous expense	5.00		5.00		5.00		5.00		5.00		5.00	
Total		445.99		445.73		445.95		471.41		445.19		472.19
Total factory cost		591.19		538.93		598.35		579.41		537.19		994.19
Interest on working capital	2.66		2.66		2.66		2.66		2.66		2.66	
Administrative and general expense	35.01		31.41		35.01		31.41		31.41		38.61	
Total		37.67		34.07		37.67		34.07		34.07		41.27
Total cost to make		628.86		573.00		636.02		613.48		571.26		1035.46
Production rate, tons per day	12.3		5.3		14.1		9.0		5.0		100.5	
Cost to make, dollars per ton	51.12		108.12[1]		45.10		68.16		114.25		10.30[1]	

[1] *Whole broccoli meal including separately dried stems would cost approximately $75.50 per ton, not including blending costs.*

TABLE VI

DAILY COSTS TO MAKE LEAF MEAL FROM VEGETABLE WASTES ROTARY DRIER - Case b (Auxiliary to Existing Bus

Item	Pea vines		Broccoli		Lima bean vines		Spinach		Beet tops		Broccoli stems	
Prime cost												
Raw materials	Nil		Nil		Nil		Nil		Nil		Nil	
Labor	$96.00		$72.00		$96.00		$72.00		$72.00		$120.00	
Total		96.00		72.00		96.00		72.00		72.00		120.00
Indirect materials												
Bags	49.20	49.20	21.20	21.20	56.40	56.40	36.00	36.00	20.00	20.00	402.00	402.00
Factory overhead												
Indirect labor												
Supervision	17.00		17.00		17.00		17.00		17.00		17.00	
Watchmen and yardmen	4.72		4.72		4.72		4.72		4.72		4.72	
Mechanics, etc.	5.00		5.00		5.00		5.00		5.00		5.00	
Office help	9.33		9.33		9.33		9.33		9.33		9.33	
Indirect expense												
Insurance	3.12		3.12		3.12		3.12		3.12		3.12	
Taxes	12.47		12.47		12.47		12.47		12.47		12.47	
Interest and fixed capital	31.18		31.18		31.18		31.18		31.18		31.18	
Workmen's compensation	1.45		1.11		1.49		1.11		1.11		1.75	
Depreciation	98.16		98.16		98.16		98.16		98.16		98.16	
Maintenance, repairs and renewals	71.42		71.42		71.42		71.42		71.42		71.42	
Power	9.87		9.87		9.87		9.87		9.87		9.87	
Oil, fuel	89.30		89.34		89.26		115.02		88.80		115.20	
Gasoline	2.20		2.20		2.20		2.20		2.20		2.20	
Factory supplies	3.19		3.19		3.19		3.19		3.19		3.19	
Miscellaneous expense	Nil		Nil		Nil		Nil		Nil		Nil	
Total		358.41		358.11		358.37		383.79		357.57		384.61
Total factory cost		503.61		451.31		510.77		491.79		449.57		906.61
Interest on working capital	2.13		2.13		2.13		2.13		2.13		2.13	
Administrative and general expense	28.14		24.54		28.14		24.54		24.54		31.74	
Total		30.27		26.67		30.27		26.67		26.67		33.87
Total cost to make		533.88		477.98		541.04		518.46		476.24		940.48
Production rate, tons per day –	12.3		5.3		14.1		9.0		5.0		100.5	
Cost to make, dollars per ton –	43.40		90.18[1]		38.38		57.60		95.25		9.36[1]	

1 *Whole broccoli meal including separately dried stems would cost approximately $63.25 per ton, not including blending costs.*

TABLE VII

ENGINEERING DATA FOR COST ESTIMATES[1,2]

Vegetable waste	Pea Vines		Lima bean vines	
Drier, type	I Portable	2 Fixed	I Portable	2 Fixed
Inlet air temperature, °F.	1030	1030	1040	1040
Exit air temperature, °F.	293	—	290	—
Drier, size external drum, feet	7 x 16	8 x 24	7 x 16	8 x 24
Drier, total capacity, lbs. water evap. per hr.	1854	5940	2166	6960
Drier, total capacity, tons as is meal per 24 hours	3.84	12.3	4.37	14.1
Drier, total capacity, tons waste per 24 hours	31.60	99.5	37.44	120
Power for drying	Gasoline	Elec.	Gasoline	Elec.
Power for cutter, screen, conveyor, and fan	Gasoline	Elec.	Gasoline	Elec.
Moisture in waste to drier, %	78.8	78.8	76.0	76.0
Moisture in whole dried waste, %	25.5	25.5	21.6	21.6
Moisture in meal, %	9.0	9.0	6.1	6.1
Lbs. meal (m.f.b.)[3] per lbs. waste (m.f.b.)[3]	.53	.53	.46	.46
Lbs. as is meal per lbs. fresh waste	.122	.122	.117	.117
Lbs. water evap. per gal. oil	80.0	95.8	93.4	112.0
Gals. oil per ton as is meal	155	121	127	105.5
Gals. gasoline per ton as is meal	10.95	—	9.6	—

1 *Total days' operation for all wastes combined = portable drier, 140 days; fixed drier 150 days.*

2 *For maximum capacity of screen, assume 60 pounds per hour per square foot.*

3 *Moisture-free basis.*

Broccoli		Spinach		Beet tops		Broccoli stems	
I Portable	2 Fixed	I Portable	2 Fixed	I Portable	2 Fixed	I Portable	2 Fixed
1090	1090	1225	1225	1035	1035	1200	1200
336	--	331	--	330	--	--	--
7 x 16	8 x 24	7 x 16	8 x 24	7 x 16	8 x 24	7 x 16	8 x 24
1657	5320	2167	6960	1466	4740	2375	7580
1.64	5.3	2.80	9.0	1.53	5.0	31.4	100.5
23.16	74.5	28.80	92.5	19.80	64	60	192
Gasoline	Elec.	Gasoline	Elec.	Gasoline	Elec.	Gasoline	Elec.
Gasoline	Elec.	Gasoline	Elec.	Gasoline	Elec.	Gasoline	Elec.
90.0	90.0	90.7	90.7	90.4	90.4	52.9	52.9
28.9	28.9	4.3	4.3	13.9	13.9	10.0	10.0
5.8	5.8	4.1	4.1	3.4	3.4	--	--
.67	.67	1.00	1.00	.78	.78	1.00	1.00
.071	.071	.097	.097	.077	.077	.524	.524
71.4	85.8	78.2	87.0	63.2	76.4	85.8	94.8
340	281	238	213	364	296	21.2	19.1
25.6	--	15.0	--	27.5	--	1.3	--

As previously pointed out, the carotene contents of the leaf meals given here are somewhat lower than would be expected in commercial processing of freshly harvested waste. Nevertheless, most of the meals are richer than alfalfa meal, which is sold on a guaranteed basis of 133 p.p.m. of carotene and 17 percent protein (Table II). With alfalfa meal of the guaranteed composition mentioned above selling in the Philadelphia market at from $53 to $86 per ton, it is apparent that the production of certain vegetable leaf meals by the methods described here can be a profitable enterprise in such an area.

Leaf meals, such as broccoli, spinach and beet tops are so rich in carotene, xanthophyll, chlorophyll and other chemical constituents[7] it is probable that they may be used to greater advantage as an industrial source of these chemicals or as a source of one or more ingredients in special feeds.